Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy

Volume 12 Article 8

January 2010

# Risk And Background Evaluation For Arsenic In Soil At A Planned Residential Development

Christopher M. Teaf
*Florida State University*

Douglas J. Covert
*Hazardous Substance & Waste Management Research, Inc.*

R. Marie Coleman
*Hazardous Substance & Waste Management Research, Inc.*

Michael Petrovich
*Hopping Green & Sams*

R.S. Murali
*Langan Engineering*

***See next page for additional authors***

# Risk And Background Evaluation For Arsenic In Soil At A Planned Residential Development

**Authors**
Christopher M. Teaf, Douglas J. Covert, R. Marie Coleman, Michael Petrovich, R.S. Murali, and Vince Yarina

# Chapter 7

# RISK AND BACKGROUND EVALUATION FOR ARSENIC IN SOIL AT A PLANNED RESIDENTIAL DEVELOPMENT

Christopher M. Teaf[1,2], Douglas J. Covert[1], R. Marie Coleman[1], Michael Petrovich[3], R.S. Murali[4] and Vince Yarina[4]

[1]*Hazardous Substance & Waste Management Research, Inc., 2976 Wellington Circle West, Tallahassee, FL 32309;* [2]*Center for Biomedical & Toxicological Research, Florida State University, 2035 E. Dirac Dr., Tallahassee, FL 32310;* [3]*Hopping Green & Sams, P.A., 123 S. Calhoun Street, Tallahassee, FL 32301;* [4]*Langan Engineering, 7900 Miami Lakes Drive Suite 102, Miami, FL 33016*

Abstract: Arsenic soil concentrations at many environmental investigation sites in Florida and other states have been reported above the current U.S. Environmental Protection Agency (EPA) soil screening level (0.4 mg/kg) and above the recently modified (2005) Florida default residential exposure Soil Cleanup Target Level (SCTL) of 2.1 mg/kg. At a site in west central Florida, arsenic soil concentrations were compiled site-wide during early routine sampling. In a state-specific 2001 study of background concentrations of arsenic in Florida soils, 27 out of the 51 counties that were evaluated contained arsenic soil concentrations above the EPA soil screening level. Ten out of the 51 counties that were evaluated had arsenic concentrations in soil regularly above the then-applicable residential exposure SCTL of 0.8 mg/kg. That study also identified elevated arsenic concentrations above FDEP's residential exposure SCTL in a geographic "belt" from Leon and Madison counties in NW Florida to Lee and Charlotte counties in SW Florida. This belt includes Hillsborough County, in which the Site is located. Based on a very extensive site database for surface and subsurface soil, it was concluded that the observed arsenic concentrations at the Site represent a naturally occurring condition (2.4 mg/kg mean and 2.8 mg/kg 95% UCL drawn from over 2,000 site soil samples). The close agreement between the mean and the 95% UCL concentrations indicates a low degree of statistical variability across the Site, and is supportive of the conclusion that the observed distribution represents naturally occurring background. Further, while the 2.8 mg/kg UCL exceeds the Florida default residential cleanup target of 2.1 mg/kg, it does not represent a significantly increased human health risk (1.3x10-6 excess lifetime cancer risk). While there was no regulatory involvement, preparation of the initial background survey, a site risk evaluation, and evaluations of local background arsenic concentrations allowed the Site owner and prospective developer to determine that the 340 acre site was suitable for residential improvement.

Key words: Arsenic, soil, background, risk assessment, planned residential development

## 1. INTRODUCTION

The project site (the Site) is a proposed residential development of no more than 500 units, with associated infrastructure, and is comprised of approximately 340 acres consisting of pasture land, agricultural land, undeveloped land, and low-lying wetland areas in Hillsborough County, Florida. Arsenic was present in soil at concentrations that exceeded the then-existing Florida Department of Environmental Protection (FDEP) Soil Cleanup Target Level (SCTL) of 0.8 mg/kg established for default residential, direct exposure scenarios (residential exposure). This FDEP SCTL for arsenic typically is applied to sites contaminated from a prohibited discharge of pollutants or hazardous substances. Originally, it was thought that the arsenic concentrations in the soil were localized in and around a small former sprayfield centrally located on the property. Thus, the FDEP SCTL was deemed an appropriate point-of-comparison. Subsequently, extensive characterization of the property, historical evaluation, and an in depth literature review, lead to the conclusion that the soil

concentrations at the property were naturally occurring. Therefore, the 0.8 mg/kg FDEP SCTL was considered not to be applicable in a regulatory framework, but was deemed useful as a guideline in the context of the property's development. In the interim, during the several-month investigation process, the 0.8 mg/kg SCTL value was revised by FDEP to 2.1 mg/kg, based upon more recent toxicological information regarding oral relative bioavailability of arsenic in Florida-specific soils (FDEP, 2005).

The initial intention of the property owner/developer and consultant group was to demonstrate, through a detailed soil management plan and an extensive characterization effort that the site-wide concentrations were below the 2.1 mg/kg unrestricted use SCTL. This would satisfy, by definition, any perceived environmental health concerns of the prospective developers, financial institutions and eventual residents/owners. After months of sampling and statistical assessments which revealed site-wide concentrations that were similar to, but slightly above the target concentration, it was decided to more formally support the position that the observed arsenic concentrations were the result of a naturally occurring background condition.

## 2. MATERIALS AND METHODS

A Phase I Environmental Site Assessment (ESA) originally was performed on the Site in October 1998. The Phase I ESA identified 11 potential areas exhibiting "recognized environmental conditions". Based on the Phase I ESA information, a limited Phase II ESA was conducted in July 1999. This investigation included the collection of soil and groundwater samples in the 11 locations that previously were identified. Arsenic concentrations in groundwater ranged from 1.19 to 21.9 micrograms per liter, below the contemporary regulatory limit of 50 micrograms per liter. In addition, soil arsenic concentrations in 9 locations at the property, primarily within the area of a former domestic sprayfield, were above the residential exposure SCTL of 0.8 mg/kg by a small margin. However, no soil concentrations exceeded the leachability-based SCTL of 29 mg/kg, so groundwater was not further investigated.

Following the Phase I and Phase II investigations, four additional characterization efforts were undertaken during the next few years to determine the nature and extent of the arsenic present in surface and subsurface soil. A total of 272 samples were collected and analyzed for total arsenic, focused primarily in and around the former sprayfield area of the Site.

In mid-2004, a Soil Management Plan (SMP) was developed for the Site in order to guide earth movement and soil sampling operations during development. The preliminary soil sampling efforts described above, those previous to July 2004, are termed "pre-SMP" efforts, while those occurring after this time are termed "post-SMP".

In addition to the 272 pre-SMP samples described above, approximately 1,800 soil samples were collected during post-SMP activities. By this time, it was clear that the former sprayfield was not an isolated area of increased arsenic concentrations. Thus, the post-SMP characterization efforts were conducted on a more site-wide basis, primarily from soil stockpiles that were assembled in anticipation of use on-site. Eighty-eight stockpiles, each composed of approximately 5,000 cubic yards of soil, were derived from excavation of planned on-site ponds or from consolidation of existing surface soils. Twenty random samples were collected from each pile and analyzed for total arsenic. Following confirmation that the soils were below 2.1 mg/kg, the soil from these stockpiles was to be redistributed on-site for use as residential lot fill material.

## 3. RESULTS

Summary statistics, as developed using the Florida UCL statistical analysis tool (FDEP, 2004a), for Pre-SMP soil samples that were collected from 0 to 2 feet below land surface (BLS) and analyzed for total arsenic are summarized in the table below. (Table 1)

*Table 1.*

| | Frequency of Detection | Mean Detected Concentration (mg/kg) | 95% UCL of the Mean Concentration (mg/kg) | Maximum Detected Concentration (mg/kg) |
|---|---|---|---|---|
| **Arsenic in soil 0 to 2 feet bls** | 48 of 68 | 1.2 | 1.8 | 6.2 |

The mean and 95% UCL of the mean concentrations are based on the non-parametric Chebyshev test because the data set is neither normally distributed nor lognormally distributed (FDEP, 2004a).

Arsenic was detected above the reported detection limit in 48 of 68 surface soil samples with a mean detected concentration of 1.2 mg/kg. The non-parametric 95% upper confidence limit (UCL) of the mean concentration for the 0-2 foot pre-SMP soils was 1.8 mg/kg, with a maximum concentration of 6.2 mg/kg. The 95% UCL represents a conservative estimate of the mean soil concentration for the site.

Some pre-SMP samples also were collected at depths greater than 2 feet BLS, in 2 foot intervals down to 8 feet BLS. Because all soil deeper than 2 feet BLS is considered to be subsurface soil with respect to human health exposure, we will address these subsurface samples as one group. The following table, (table 2) presents the summary statistics for the pre-SMP subsurface soil analytical results.

*Table 2.*

| Arsenic in Soil | Frequency of Detection | Mean Detected Concentration (mg/kg) | 95% UCL of the Mean Concentration (mg/kg) | Maximum Detected Concentration (mg/kg) |
|---|---|---|---|---|
| **> 2 feet bls** | 193 of 204 | 4.7 | 5.2 | 160 |
| **2 to 4 feet bls** | 65 of 68 | 3.8 | 5.1 | 25 |
| **4 to 6 feet bls** | 62 of 68 | 7.3 | 9.9 | 160 |
| **6 to 8 feet bls** | 57 of 68 | 3.1 | 4.1 | 43 |

Arsenic was detected above the reported detection limit in 193 of 204 subsurface soil samples. The mean detected concentration for the data is 4.7 mg/kg (lognormal), and the 95% UCL of the mean concentration is 5.2 mg/kg. Arsenic was detected in subsurface soil (greater than 2 feet BLS) at a maximum concentration of 160 mg/kg in one sample from the 4 to 6 foot interval at the extreme southern property boundary. It should be noted that this 160 mg/kg concentration is approximately four times greater than the next-highest value (43 mg/kg in the 6-8 foot interval), and likely represents a statistical outlier.

A total of 1,759 post-SMP samples were collected from the 88 stockpiles described above. The version of the Florida UCL tool available at the time functionally was limited to evaluations of less than or equal to 1,000 samples, so U.S. EPA's ProUCL tool (U.S. EPA, 2002) was used for calculations involving more than 1,000 samples. The overall 95% UCL of the mean concentration for all available post-SMP samples is 2.4 mg/kg (mean concentration of 2.2 mg/kg). As shown on the next table, (Table 3) when pre-SMP samples from all depth intervals and all available post-SMP samples are combined, the site-wide mean concentration for these 2,031 samples is 2.4 mg/kg and the site-wide 95% UCL concentration is 2.8 mg/kg.

*Table 3.*

| Arsenic in soil from | Number of Samples | Mean Detected Concentration (mg/kg) | 95% UCL of the Mean Concentration (mg/kg) | Maximum Detected Concentration (mg/kg) |
|---|---|---|---|---|
| **88 Post-SMP Stockpiles** | 1,759 | 2.2 | 2.4 | 26 |
| **Post-SMP and Pre-SMP Samples** | 2,031 | 2.4 | 2.8 | 160 |

The mean and 95% UCL of the mean concentrations are based on the non-parametric Chebyshev test because the data is neither normally distributed nor lognormally distributed (U.S. EPA, 2002).

Subsequently, an independent, nearby off-site evaluation of background arsenic concentrations in surface soil concluded that approximately 3 mg/kg was indeed a reasonable estimation of regional conditions.

## 4. DISCUSSION

The mineralogic make-up of the soil at the Site, along with the horizontal and vertical distribution of the data, strongly suggests that the arsenic is of a naturally occurring origin, rather than the result of anthropogenic historical release of, for example, arsenic-containing herbicides or pesticides at the land surface. In particular, the soils in the vicinity of the Site are rich in phosphorus (e.g., phosphate), which is known to be associated with elevated levels of arsenic in soils, including Florida soils.

Arsenic concentrations at many Florida sites have been reported above the current U.S. Environmental Protection Agency (EPA) soil screening level (0.4 mg/kg) and above the then-current FDEP default residential exposure SCTL of 0.8 mg/kg (Chen et al., 2001). That 0.8 mg/kg value was modified to 2.1 mg/kg by the FDEP in February 2005 based primarily on modifications to relative oral bioavailability of arsenic from Florida-specific soils. In the Chen et al. study of background concentrations of arsenic in Florida soils, 27 out of the 51 Florida counties that were evaluated contained arsenic concentrations in soil above the EPA soil screening level (Chen et al., 2001). Ten out of the 51 counties that were evaluated had arsenic concentrations in soil above the FDEP contemporary residential exposure SCTL of 0.8 mg/kg. That same study also identified generally elevated arsenic concentrations above FDEP's residential exposure SCTL in a geographic "belt" from Leon and Madison counties (in northwest Florida) to Lee and Charlotte counties (in southwest Florida). That belt includes Hillsborough County, in which the project Site is located. Surficial soils in this geographic belt are predominantly sandy, but include a variety of relatively clayey substrata, limestone, and organic deposits. Most importantly, this geographic belt also includes soils from all four types of phosphate rock deposits that occur in Florida. A comparison of the phosphate rock deposits in Florida and potential arsenic contaminated sites shows that Florida phosphate deposits may be a source of elevated arsenic concentration in soil in those areas (Blakey, 1973). Furthermore, in proceedings of the Fertiliser Society, data were presented showing an arsenic concentration range from 4 mg/kg to 25 mg/kg with a reported average of 11.29 mg/kg in 15 central Florida phosphate rock samples (van Kauwenbergh, 1997). In at least one area on the Site, this pattern of elevated arsenic concentrations in segregated strata has been confirmed. A shelly layer from 3 to 5 feet below land surface was identified in the northeast portion of the site that contains notably higher concentrations of arsenic than the layers above and below (Langan, 2005).

Soil analytical data collected for the property clearly support the conclusion that the concentrations of arsenic in soil at the property are due to natural geologic conditions (i.e., the presence of phosphate deposits and related materials). Further, in the case of typical anthropogenic releases of chemicals, including arsenic-containing mixtures, a vertical pattern of decreasing concentration with increasing depth generally is observed, and there customarily are one or more localized source areas or some historical soil disturbance. No such disturbances or source areas were reported during initial pre-SMP site investigation activities and, as shown on the following table (table 4), the 0 to 2 foot soil interval exhibits the lowest frequency of detection, the lowest average and the lowest 95% UCL concentrations when compared with the other, deeper intervals.

*Table 4.*

| Arsenic in Soil | Frequency of Detection | Mean Detected Concentration (mg/kg) | 95% UCL of the Mean Concentration (mg/kg) | Maximum Detected Concentration (mg/kg) |
|---|---|---|---|---|
| **0 to 2 feet bls** | 48 of 68 | 1.2 | 1.8 | 6.2 |
| **2 to 4 feet bls** | 65 of 68 | 3.8 | 5.1 | 25 |
| **4 to 6 feet bls** | 62 of 68 | 7.3 | 9.9 | 160 |
| **6 to 8 feet bls** | 57 of 68 | 3.1 | 4.1 | 43 |

FDEP states in multiple department Rules that "…the Department shall not require site rehabilitation to achieve a CTL for an individual contaminant that is more stringent than the site-specific background concentration for that contaminant…" No final guidance document regarding development of site-specific background concentrations currently is available from FDEP. However, the characterization and sampling effort that was conducted at the Site, even though the intent was not for the purpose of establishing site-specific background, represents a reasonable and thorough approach from which it is possible to conclude that the arsenic in soils at the Site represents a naturally occurring background condition. Thus, an appropriate site-specific SCTL may be the previously described site-wide 95% UCL of the mean concentration, 2.8 mg/kg.

To further buttress the background/data characterization line of reasoning, a more in-depth, risk-based discussion of the FDEP SCTL for arsenic is in order. The historical promulgated direct exposure residential SCTL for arsenic, at the time that all pre-SMP work was conducted, was 0.8 mg/kg (FDEP, 1999), based on a 30-year residential exposure and a target cancer risk of $1x10^{-6}$ (a population increase of one cancer in one million persons above the expected cancer rate). Over a several-year period, modifications were proposed to the SCTLs in general based on revised assumptions for parameters such as body weight, skin surface area and inhalation rate. In addition, chemical-specific adjustments were proposed for the arsenic SCTL based on studies showing reduced oral bioavailability of arsenic in Florida-specific soils.

This Relative Bioavailability Adjustment (RBA) factor was addressed in detail by the Department and several groups which were formed by FDEP for the purpose of providing technical recommendations to the Department for its consideration in agency rulemaking. The Methodology Focus Group (MFG) of the Contaminated Soils Forum met numerous times over several years to review the arsenic issue and to consider in detail the available scientific information in support of specific assumptions. In March 2003, the MFG presented its findings to the Department in the form of a letter (DeMott, 2003) which recommended that a Relative Bioavailability Adjustment of 25% (= bioavailability correction factor of 4x) be used, based upon the results of a primate study, using a range of Florida soils, that was conducted at the University of Florida, and was funded by the Department (Roberts et al., 2002).

After further review in the context of rule development for Chapter 62-777, the Department concluded that a RBA of 33% (= bioavailability correction factor of 3x) was appropriate (UF/FDEP, 2004), but provided no additional technical foundation for that specific decision. This 3-fold correction factor to account for bioavailability was incorporated into a proposed arsenic SCTL of 2.1 mg/kg (FDEP, 2004b) that subsequently was finalized and adopted in February of 2005 (FDEP, 2005). This 2.1 mg/kg value still has as its basis a target cancer rate of one in one million and the underlying assumption of 30 years of exposure. It should be noted that using a correction factor of 4x, as recommended to the Department by the MFG, would result in a proposed arsenic SCTL of 2.8 mg/kg, also a value which is based on cancer protection at the one-in-one million rate. The overall 95% UCL concentration of 2.8 mg/kg for the Site represents a very nominal increased cancer risk ($1.3x10^{-6}$ or 1.3 in one million) as compared with the current FDEP default residential SCTL of 2.1 mg/kg.

As of February 2005, the following 20 states utilize a default screening target concentration that is less restrictive than 2.8 mg/kg, with values ranging from 3.9 mg/kg to 24 mg/kg:

| | | |
|---|---|---|
| Arizona | Massachusetts | New York |
| Connecticut | Maine | North Carolina |
| Illinois | Minnesota | Ohio |
| Indiana | Missouri | Pennsylvania |
| Iowa (deep soils) | New Hampshire | Texas |
| Kansas | New Jersey | Washington |
| Kentucky | New Mexico | |

Further, these and other states have granted actual cleanup concentrations on a site-specific basis which exceed even the 24 mg/kg level. At a number of Florida sites, the U.S. EPA has implemented

soil cleanup targets of 20 mg/kg or more in residential or other unrestricted land use circumstances. Thus, while the FDEP has exercised its prerogative to set a highly conservative guideline with respect to protective soil arsenic concentrations, an exceedance of that 2.1 mg/kg criterion does not necessarily indicate a hazard to human health.

## 5. CONCLUSION

In summary, it is apparent that the observed arsenic concentrations in soil at the Site represent a naturally occurring condition (2.4 mg/kg average and 2.8 mg/kg 95% UCL concentration drawn from over 2,000 samples from all portions of the Site). The close agreement between the mean concentration and the 95% UCL concentration indicates a low degree of statistical variability across the Site, and is supportive of the conclusion that the observed distribution represents naturally occurring background. No historical activities on the Site are known or expected to have resulted in arsenic use or releases on the property. Further, although the 2.8 mg/kg 95% UCL level exceeds the FDEP default residential cleanup target of 2.1 mg/kg, it does not represent a significantly increased human health risk, as evidenced by a cancer risk level of $1.3x10^{-6}$ compared to the default goal of $1.0x10^{-6}$. Given the nature of typical well-developed residential neighborhoods (i.e., limited areas of bare soil), coupled with the fact that few residential activities involve daily direct contact with bare soil, exposures at the Site will not approach the conservative assumptions that were relied upon to develop the FDEP default residential cleanup target of 2.1 mg/kg (i.e., 350 days/year exposure for 30 years at 200 mg/day assumed soil ingestion, plus dermal and inhalation contact).

## REFERENCES

Blakey, A.F. 1973. The Florida phosphate industry: a history of the development and use of a vital mineral. Cambridge, MA, Harvard University Press.

Chen, M., Ma, L.Q., Hoogeweg, C.G., and Harris, W.G. 2001. Arsenic Background Concentrations in Florida, U.S.A. Surface soils: Determination and Interpretation. Environmental Forensics, Vol.2, 117-126.

DeMott, R.P. 2003. Chairman's Letter to Mr. John Ruddell, Director, FDEP Division of Waste Management. Dated March 7, 2003.

FDEP (Florida Department of Environmental Protection). 1999. Chapter 62-777, F.A.C. Effective Date August 5, 1999.

FDEP (Florida Department of Environmental Protection). 2004a. Florida UCL tool version 0.97. Software for calculating 95% upper confidence limit of mean concentrations.

FDEP (Florida Department of Environmental Protection). 2004b. Chapter 62-777, F.A.C. Workshop Draft. October 2004.

FDEP (Florida Department of Environmental Protection). 2005. Chapter 62-777. Contaminant Cleanup Target Levels. April 17, 2005.

Langan (Langan Engineering & Environmental Services, Inc.). 2005. Personal communication.

Roberts, S.M. et al. 2002. Measurement of arsenic bioavailability in soil using a primate model. Toxicological Sciences 67: 330-310.

UF/FDEP. 2004. Technical Report: Development of Cleanup Target Levels (CTLs) for Chapter 62-777, F.A.C. Prepared for the Florida Department of Environmental Protection by University of Florida, Center for Environmental & Human Toxicology. Gainesville, FL.

U.S. EPA. 2002. ProUCL software v 3.00.02. National Exposure Research Laboratory Technical Support Center.

Van Kauwenbergh, S.J. 1997. Cadmium and Other Minor Elements in World Resources of Phosphate Rock. Proceedings No. 400. The Fertiliser Society, London, October 9, 1997.